REMARKS

The Office action of August 24, 2006 has been carefully considered and the application has been amended accordingly.

Claims 7-12 are present in the application.

Claims 7-11 have been rejected under 35 U.S.C. 112 in view of the recitation in parent claim 7 that the method comprises "inducing an alternating magnetic field <u>much less than saturation</u> in the steel wires...." Applicants respectfully submit that a person of ordinary skill in the art would have no difficulty in understanding this expression, and it particularly points out what applicants consider to be their invention. With any particular type of steel there is a magnetic field that leads to saturation; for some inspection methods it is necessary to operate with magnetic fields that are close to (or even higher than) the saturation value such as, for example, in US 5 414 353 (Weischedel) cited in the Office action. In contrast the present invention does not require saturation. Instead, it requires much smaller magnetic fields. The exact magnitude of those fields is not of relevance to the invention, as long as they are "much less than saturation" as recited in parent claim 7. It is submitted that the claim language properly defines the invention and clearly distinguishes the invention over the prior art.

Claims 7-9 have been rejected under 35 U.S.C. 102(b) as being anticipated by WO 02/06812 (BERGAMINI, A.E.) As regards this rejection, an Appendix is attached for the Examiner's convenience which is a translation of the relevant parts of the document. This citation has a similarity in that it aims to detect broken wires in a steel cable. However, it uses a totally

different approach to do so, in which a coil around the cable is used to induce a magnetic field in all the wires, and then sensors are used to detect the resulting flux at the ends of the wires (protruding from the end of the cable). The present invention is clearly distinguished from this citation in using a probe "adjacent to the cylindrical surface of the structure..." to induce an alternating magnetic field, the magnetic field being <u>much less than saturation</u>, and monitoring the alternating magnetic flux density <u>near the cylindrical surface</u> of the structure <u>in the vicinity of the said probe</u>. The present invention is also distinguished by determining a <u>parameter indicative of stress</u> in the steel wires; no such teaching or suggestion is seen in the recited document.

In contrast, this citation (paragraph 12 (page 7 lines 3-4)) suggests use of either DC or AC current; and figure 3 shows graphically that the steel is taken to near saturation. Secondly, this citation necessitates observing the flux at the exposed end of the cable, rather than around its circumferential surface. And thirdly, it does not measure a parameter indicative of stress, teaching that the measured voltage depends only on the parameters enumerated at the end of paragraph 7.

It will be appreciated that the method claimed in the present invention is conceptually completely different from that of this citation. The citation involves inducing a magnetic field using a single coil that surrounds the entire steel cable, and then monitoring the magnetic flux density at the exposed ends of the wires. This relies on the principle that if there is a break in a wire, then the magnetic flux will not readily pass through the break, and therefore the flux density at the end of the wire will be reduced. This can indeed detect a broken wire,

at least as long as the break is very close to the end. It suffers from two major disadvantages: it is only applicable if the ends of the wires are exposed; and if the break is not close to the end, the magnetic field will redistribute between the steel wires, so that the break will not be detectable at the exposed end.

The present invention is based on a completely different principle: that of measuring the mechanical stress in the steel wires. It uses one or more electromagnetic probes around the circumference, each probe incorporating two features: an electromagnetic coil to induce the required alternating magnetic field; and also means for monitoring the alternating magnetic flux density near the curved surface of the structure. In order to monitor stress, the magnetic flux density must be monitored in the immediate vicinity of the electromagnetic coil that is inducing the magnetic field. Therefore the magnetic flux density is monitored by the same probe that induces the field.

Since it has never hitherto been suggested that such a flexible elongate structure should be monitored by measuring the stresses in the steel wires, it can hardly be obvious to perform such a monitoring procedure using an electromagnetic inspection procedure.

Claim 12 has been rejected under 35 U.S.C. 103(a) as being unpatentable over US 5,414,353 (Weischedel). This patent describes a way of detecting certain types of flaw in cables or pipes. It uses an inspection device with permanent magnets arranged to generate two magnetic flux circuits through the object, in opposite longitudinal directions. The device is scanned rapidly along to induce circumferential eddy currents, so

that any longitudinal crack or loose wire changes the eddy current as the device passes over that fault (column 6 lines 36-37; column 7 lines 38-62). The strength of the magnetic field in the object should be close to magnetic saturation, to suppress background noise (column 11 lines 50-51 and column 12 lines 51-58). Again that is a totally different approach to that of the present invention. Further, this would not even be able to detect broken wires, as they would not affect the circumferential eddy currents!

The present invention is clearly distinguished from the citation in inducing an <u>alternating</u> magnetic field (rather than using permanent magnets); in that the magnetic field is <u>much less than saturation</u> (rather than being close to saturation); in determining a <u>parameter indicative of stress</u>; and in detecting if <u>wires are broken</u>.

In contrast, the citation emphasizes that by using a magnetic field close to saturation the effects of "permeability variations", for example due to "localized stress variations", are eliminated from the measurements (column 11 lines 32-51). Thus the citation excludes any stress effects from its measurements. Furthermore, as commented above, the citation does not detect a broken wire, as such a break does not affect the circumferential eddy currents.

A further fundamental distinction is that the present invention can take measurements with a stationary probe, for example taking measurements "no more than 0.5 m from the end-fitting" (page 11 line 14), that is to say measurements are made with the probe at a particular position. In contrast the citation necessitates moving the magnet device along the object

at a speed of at least 100 ft/min, and possibly greater than 18 mph (col. 7, lines 39-40). It will therefore be appreciated that the present invention is clearly distinguished from the citation.

In view of the foregoing remarks, reconsideration of the application is requested and allowance of claims 7-12 is courteously solicited. Applicants' undersigned attorney would welcome a telephone conference with the Examiner to expedite allowance of the application.

Respectfully submitted,

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Date

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I hereby certify that this correspondence is being transmitted by facsimile this day to Examiner Ledynh at the United States Patent and Trademark Office, Art Unit 2862, to fax No. 571-273-8300.

11-24-2006 W.H. Holt
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Appendix

(Partial Translation)

WO 02/06812

Title: **Method and Device for the Nondestructive Examination of Steel Cables in Anchorages**

Applicant: EMPA (Switzerland)

Abstract:

The invention relates to a method and device for the non-destructive examination of steel cables in anchorages. The inventive method is based on a magnetic flux measurement. A magnetic field B is induced in the cable (2) to be examined by means of a coil (1). The magnetic flux lines (3) are concentrated in the steel as compared to the surroundings due to the higher magnetic permeability of the steel and extend approximately in parallel to the wire axis. The flux of the magnetic field can be measured on the front face (4) of every undamaged wire (2) through the end face (4) of the cable (2). If, as shown in Figure 1b, a break (5) perpendicular to the longitudinal axis of the cable (2) is present between the coil (1) and the end face (4) of the wire (2), the magnetic flux is weaker or reduced on the end face (4) of the wire (2). The break width of the gap (5) influences the magnetic flux, measured on the end face (4) of the wire (2). For a cable that consists of a plurality of wires the measurement of the magnetic flux on the end face (4) of every single wire (2) can be used to determine whether the wire is still in a good condition or if it is cracked or completely

broken.

Page 1 paragraph 1

The invention provides a process and a device for nondestructive testing of steel cables in the anchorages at their ends. By the term steel cable or rope should be understood in the following as encompassing sealed rope, stranded wire ropes, parallel wire cables, external tension members etc. Such steel cables, which are used as basic elements of bridges and other buildings, must be examined occasionally for their condition, in order to ensure security and load-carrying capacity of the structures.

Page 5 line 6 (paragraph 0009)

... During the measurement of the magnetic flux for instance in the wires of a steel cable one proceeds according to a similar principle: a magnetic field B is induced, as shown in figure 1a, by means of a coil 1 into the wire 2 which is to be examined. The lines of flux 3 are concentrated in it due to the larger magnetic permeability of the steel of the wire 2 in comparison to its surroundings, and run approximately parallel to the wire axis. At the end face 4 of each intact wire 2 of a wire rope the flux of the magnetic field emerging through the end face 4 of the wire 2 is individually measurable. The magnitude of the magnetic flux depends on the following parameters: 1. the diameter of the wire, 2. the material-specific permeability of the wire, 3. the distance between the coil and the front surface of the wire end, 4. the current flowing in the coil, and 5. the geometry of the coil (diameter and number of turns).

[0010] If as shown in figure 1b there is a break 5 perpendicular to the longitudinal axis of a wire 2 between the coil 1 and the end face 4 of the wire 2, the magnetic flux at the end face 4 of the wire 2 is weakened or reduced. In addition to the above-mentioned parameters, the width of the break, i.e. the width of the gap 5, also has an influence on the flux of the magnetic field B measured at the end face 4 of the wire 2. With a tension member or a rope which consists of several wires, by a measurement of the magnetic flux at the end face 4 of each individual wire 2, you can determine whether the wire is still in a good condition or damaged or is completely broken.

[0011] Since in practice the magnetic field B is not completely homogeneous over the whole cross section of the tension member 2 or the rope 2, and also can't be accurately calculated, one must compare the magnetic flux at an individual wire 2 with the flux at the wires in a geometrically equivalent situation in the rope, i.e. at the same distance from the longitudinal axis of the rope. If the signal measured at the end of an individual wire differs from the measured signals at the other wires with equivalent geometrical situation, this indicates that the wire concerned is probably damaged. By application of a suitable computer model the comparison between the measured values for wires in different situations can be facilitated, and this enables an assessment of the condition of the individual wires and the rope altogether to be made rapidly and reliably.

[0012] In figure 2 a device is schematically represented for carrying out nondestructive testing of cables in regions of their anchorages or end fittings, in which the cable or rope, its end fitting 10 and the coil 1 are shown in longitudinal section. Basically the device consists of a coil 1, a current source 6

with a function generator 7, and a data acquisition unit 8 with a magnetic flux measuring probe 9. The rope 2 to be examined is fixed in the end fitting 10, while the ends of the individual wires of the rope 2 stick out of the end fitting 10, or are at least bound into it so that the end faces 4 of these wires 2 are accessible. The accessibility of these end faces 4 is a fundamental requirement for the application of the testing method. Where the faces 4 are covered or cast into the end fitting 10, they must first be exposed. This exposing can take place however in practice without weakening the end fitting 10 of the rope 2. The material beyond the end faces 4 takes no more tension forces, and after examination has been carried out the faces 4 can be embedded as before or covered with other protective agents. Often the final sections project some few centimetres beyond the end fitting 10 of the rope end, and are covered with a protective cap. In this case only the protective cap must be removed and the testing method be used straightaway. The examination can take place thus without destruction, i.e. the end fitting 10 does not have to be destroyed, and its function (for example in a bridge) hence remains during the examination. For practical execution the coil 1 is put on around the rope 2 which is to be examined, and the power source 6 supplies a DC or alternating voltage specified by the function generator 7, which is supplied to this coil 1. Now the magnetic flux induced in the rope 2 is measured by placing the magnetic flux measuring probe 9 on the individual wires of the rope. This magnetic flux measuring probe 9 may be a Hall-effect probe, or magnetoresistors or other solid state sensors can be used. The measured magnetic flux at the end faces of each individual wire are stored in the data acquisition unit 8. As data acquisition unit a measuring computer with a multichannel analogue/digital converter is suitable, because several objects (i.e. wires) are examined in

the same procedure. If the wires are intact, the magnetic flux of all the wires concentric with the longitudinal axis of the rope should be identical. At each radial distance from the rope's longitudinal axis, where individual wires lie, there is a typical magnetic flux. The magnetic flux at all these wires can be compared now with one another, and for each radial position of the wires.

[0013] The figures 3a-d show some practically obtained measurements in the form of diagrams, the abscissa showing the coil current, I, in kA, and the ordinate showing the signal, U, measured by the Hall sensor in mV . These results were obtained by measurements on two single wires. The wires had a diameter of 17 mm; they were of different steel alloys, one of stainless steel (magnetically soft) and one of structural steel (magnetically hard). A zero-measurement was performed with intact wires (NO d). Afterwards one section of length 100 mm was cut from the end of each wire and put back again, in order to produce a gap d. Flux measurements at the face of the wires were then made, with variable break widths and/or gap widths (d= 0 mm, d = 2mm, d = 5mm, d = 10mm), in order to simulate breaks of different width. The influence of the distance of the field coil to the measuring point was examined likewise. The quantity of the data and thus the reliability of the measurements were increased with the fact that alternating current was used for the measurement, and that the flux was measured as function of the coil current. The measured curve shows typical hysteresis behaviour of the examined ferromagnetic materials.

[0014] As is clear from the graphs, introducing a fracture into the steel wires has a clear influence on the measured magnetic flux. The mid-point upward gradient of the curves decreases with

increasing break width, independently of the distance between field coil and measuring point. The diagram of figure 3a was determined with a wire (diameter = 17mm) of stainless steel. The distance between coil and measuring point was 100mm. In the diagram of figure 3b the hysteresis curves for the same break widths d are indicated, however with the distance between coil and measuring point increased to 300 mm. In figure 3c the hysteresis curves with the same break widths are shown, but with magnetically hard structural steel wire (diameter = 17mm). Figure 3c shows the results with a distance between coil and measuring point of 100mm, and figure 3d with this distance being 300mm.

[0015] Figure 4 shows a device with a coil body 11 of aluminum or plastic, in two separate parts, and associated rotating mechanism 12, for carrying out the testing method. Such a coil body 11 has an approximate length of 400mm and has a clear inside diameter of somewhat more than 200mm, in order to be able to examine cable up to a usual size of 200 mm diameter....